Using Science Writing Heuristics to Increase Conceptual Understanding of Properties of Matter and Property Changes with 8th Grade Students

by

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A Thesis Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Arts

Approved May 2015 by the
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ARIZONA STATE UNIVERSITY

August 2015

ABSTRACT

This teacher research study examined the effects of utilizing an intervention of Science Writing Heuristics (SWH) as a tool to increase learning during laboratory activities. Five of my eighth grade general science classes participated in this study. Two classes utilized SWH during their laboratory activities (the treatment group) and three classes performed and wrote up their labs in the more traditional, teacher-directed approach (the control group). The assessment scores of the students in the treatment group were compared to the assessment scores of the students in the control group. The post-assessments were analyzed utilizing a t-test. I was teacher in this study and the teacher of all five classes. Data from 41 students were analyzed in this study. A pre-assessment, six laboratory activities, instruction, and a post-assessment occurred within three weeks. The assessments were generated by myself and I performed a t-test using a two-sample analysis, assuming unequal variances ($n=16$ for treatment group, $n=25$ for control group) to compare the post-assessments from each group. Results indicated that there was no significant difference between the post-assessment scores of the treatment group with the post-assessment scores of control group ($p=0.25$). However, the t-test results revealed that when the pre- and post-assessments were compared, there was a significant difference ($p=<0.05$ for treatment group, $p=<0.05$ for control group). Each group showed considerable cognitive improvement between pre-assessment (mean scores: 52%-treatment group and 53%-control group) and the post-assessment (mean scores: 72%-treatment group and 80%-control group). This suggests that the presentation of the curriculum lacked a clear distinction between the treatment group and the control

group yet benefited most students. Due to circumstances described in the limitations, further research is warranted.

ACKNOWLEDGMENTS

This thesis would not have been possible without the guidance and support of several individuals in who one way or another contributed to the completion of this study.

I am grateful to Dr. Julie Luft and Dr. Josephine Marsh for their patience and encouragement as they guided me through this study.

I would like to thank my family for their understanding when this study monopolized my time.

I especially want to thank my best friend and husband, Michael Drobitsky. You provided me with never-ending emotional support. You gave me your time when you spent numerous hours proof-reading. You never wavered in your confidence in me, even when I struggled. Thank you Honey, I love you.

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INTRODUCTION

Background

Technologically our world is changing rapidly; touching most facets of the labor force. Today's students must to be prepared to meet the demands of our ever-changing labor force if our country is to compete economically (Casey, 2012; National Science Teachers' Association [NSTA], 2011). The responsibility to prepare students to meet these demands falls onto the educational system, more specifically with teachers. The National Science Teachers Association (NSTA) recognizes the strong connection between the skills needed for success in the 21st century and a solid education in science; "exemplary science education can offer a rich context for developing many 21st-century skills, such as critical thinking, problem solving, and information literacy especially when instruction addresses the Nature of Science [NOS] and promotes the use of science practices" (NSTA, 2011 p.1). These practices contribute to the development of a well-prepared workforce for our future (NSTA, 2011).

Preparing students for the workplace that awaits them has always been a goal of education. Discussions about students' secondary and post-secondary science education reveals that the science courses are not adequately preparing its students with the skills needed to succeed in industry have been occurring for many decades (Hauser, 1951; Obama, 2009). One member of the American Institute of Chemistry stated that "while education is teaching the fundamentals, it is not preparing students to apply that knowledge (Hauser, 1951, p.643). Years of rote memorization and honing test taking strategies have failed our students when it comes to being able to reason. Those opinions were reiterated more recently; Senator Bob Casey, Chairman of The Joint Economic Committee, in his 2012 report declared

> Half or more of economic growth in the United States over the past fifty years is attributable to improved productivity resulting from innovation… The need for workers with STEM [science, technology, engineering and math] skills is heightened in today's global economy…. Improving access to quality STEM education will strengthen the caliber of the U.S. workforce, drive economic growth, and keep the U.S. competitive (Casey, 2012 p.1).

Additionally, the need is just as great for people with general STEM skills as it is for those with specialized STEM skills (Casey, 2012). Large corporations and small businesses are reporting that they must go outside the United States to hire employees with the science and critical thinking skills that they seek. Casey (2012) acknowledges that building a strong STEM workforce that leaves our country competitive in the global economy is a challenge for educators and policymakers.

These past and current discussions should focus our attentions on the disconnect between students anticipated skill set and that which they currently receive. United States President Barack Obama (Obama, 2009a), citing data-based evidence, declared that he was making STEM education a national priority affirming that "even as we've worked to end this immediate crisis, we've also taken some historic measures to build a new foundation for growth and prosperity that can help secure our economic future for generations to come" (Obama, 2009a, para.3).

With these words, President Obama (2009a) began a national overhaul to the educational system;

> ….America will not succeed in the 21st century unless we do a far better job of educating our sons and daughters…. In an economy where knowledge is the most valuable commodity a person and a country have to offer, the best jobs will go to the best educated…. In a world where countries that out-educate us today will out-compete us tomorrow, the future belongs to the nation that best educates its people" (para. 5).
>
> The United States, a country that has always led the way in innovation, is now being outpaced in math and science education…. And most employers raise doubts about the qualifications of future employees, rating high school graduates' basic skills as only "fair" or "poor" (para. 6).

President Obama gave national voice to these concerns and declared something will be done. He tied federal funds to his Race to the Top program and declared that schools would have to prove themselves and compete for those funds. Schools would have to increase both the number of college-ready students and the number of students taking STEM coursework (Obama, 2009a).

NSTA recognizes that science education is the ideal setting to develop 21st - century skills such as critical thinking and problem solving (NSTA, 2011). It is for this reason that this study will examine the efficacy of incorporating Science Writing Heuristics (SWH) into students' laboratory experiences. The expectation is that SWH will foster the learning of content in addition to fostering critical thinking and problem solving skills thus enhancing their college and career readiness skills.

In a teacher-directed class setting, students are often provided the problem to solve and then asked to think of a hypothesis. Then, typically, they receive lab procedures that state the materials they will use and how they will conduct their experiment. This format is much like reading and following a recipe in a cookbook with a picture of what the finished product should resemble. Occasionally students do not achieve their expected outcome. They may repeat the process; then report that their hypothesis was wrong. Science teachers, myself included, often find that students have a limited understanding of the phenomena they studied. This limited understanding does not foster critical reasoning or problem-solving skills. Researchers, in an examination of thirty years of data that compared students' lab experiences to student gains, concluded the traditional approach to lab routines does not result in student learning (Greenbowe & Hand, 2005).

Students should be conducting laboratory experiments to provide them with opportunities to develop a solid understanding of the content, reasoning skills and the NOS (NSTA, 2007). The rote exercises of traditional lab experiences contribute more to confirm a process than to help students to make connections from what was learned in their lab to the real world (NSTA, 2007).

Science Writing Heuristics

The (Science Writing Heuristic) SWH is a tool to improve student experiences, specifically in laboratory settings. SWH is a writing-to-learn process that provides students with opportunities to (a) scaffold new information to prior information, (b) generate meaning from their laboratory experiences, (c) challenge misconceptions with cognitive conflicts, (d) socially interact with their peers throughout the entire process, and (e) utilize discourse and writing to clear up any confusion. These facets of SWH will encourage students' reasoning skills thereby putting the students on the path towards becoming scientifically literate. SWH uses templates (See Table 1) to guide both students and teacher towards improved learning; utilizing the benefits of both writing and verbal discourse.

Figure 1:

Science Writing Heuristic Templates

The Teacher Template	The Student Template
1. Teacher engages students to elicit pre-knowledge and gain understanding of the scientific context into which the laboratory is situated.	1. Questions: What are my questions? 2. Test and Collect Data/Observation: What did I do? What did I see?
2. Teacher may design pre-laboratory investigations such as brainstorming, developing questions about the topic, or expressing prior knowledge.	3. Claims: What can I claim? 4. Evidence: How do I know? Why am I making these claims?
3. Participation: Teacher encourages students to engage in an inquiry/laboratory investigation.	5. Reading: How do my ideas compare with others?
4. Negotiation I: Teacher guides students to think about the meaning of their data through journal writing.	6. Reflection: How have my ideas changed?
5. Negotiation II: Teacher encourages students to negotiate their understandings of the data with their peers. Students are encouraged to make knowledge claims to state explanations for their data.	
6. Negotiation III: Teacher assists students to compare their ideas to textbook and on-line encyclopedia.	
7. Negotiation IV: Teacher encourages students to communicate their current understandings of the investigation in a more polished form, i.e., writing a poem, letter or report, or creating a presentation or poster	
8. Exploration: Teacher engages students to bring reflection to their understanding of the laboratory concepts.	

Data Source: Implementation of the science writing heuristic (swh) approach in 8th grade science classrooms by Nam, Choi, and Hand, International Journal of Science and Mathematics Education (2011) 9: 1111Y1133 # National Science Council, Taiwan 2010

The SWH process begins with discourse between the students and the teacher, at the students' current level of understanding. This provides an avenue for scaffolding, enabling the teacher to better address the students' specific learning style and pre-knowledge. With carefully planned and guided prompting, student questioning will occur naturally, leading students to want to "find out" or discover knowledge for themselves. If necessary, the teacher uses prompts to redirect when the topic of the desired discussion begins to go astray.

Once the students have decided what they plan to investigate and frame their own questions, they will be more motivated to continue. This "buy-in" to the process is because the students feel that they themselves are in control of their learning and are learning what they want to know. This active engagement in the learning process leads to increased conceptual understanding (Hand, Wallace, & Yang, 2004).

As results are discussed and compared between students, there is an opportunity to shape one's understanding of the content. Britton explains (as reviewed by Rivard and Straw, 1999, p. 568), mental process occurring in a student's mind as the student discusses and works out his or her reasoning is the result of the communication of ideas. Once students have had this opportunity, they then start to link new knowledge to existing knowledge. Often, students draw upon evidence to make their conclusions (Hand et al., 2004).

SWH incorporates writing as a learning tool versus just a reporting tool. When utilizing this type of writing (writing-to-learn), students "generate and clarify their understanding of scientific concepts for themselves, rather than simply communicating with a teacher for evaluation" (McDermott, 2010, p.32). This 'active engagement' in writing enables metacognition and increases conceptual understanding (Balgopal & Wallace, 2013; Metz, 2012; Wallace, Hand, & Prain 2004). These activities often require that students write for a specific audience; this may be their classmates, students in another content course or even younger students. Writing to an audience other than their teacher forces the students to express their thoughts clearly and coherently.

Writing to learn can also benefit students when they peer-review and edit each other's work. Editing another student's work is shown to improve a student's own writing skills (Ende, 2012). If the reader is unclear about something; they ask for clarification. The readers are free to make comments and suggestions. This process supports students, especially those with weaker writing skills, in creating a well-written and well-understood final report.

There are several additional gains to student learning when writing. According to Rivard and Straw (1999), when students are required to list, describe or define, processes involved in writing, they are focused on concepts in isolation. However, when performing analytical tasks such as explaining real-world applications of scientific concepts "learners connect these into an integrated web of meaning" (p. 568). Brown and Campione (1990) argued that "the burden of explanation is often the push needed to make students valuate, integrate and elaborate knowledge in new ways" (p. 114). Ultimately, students can understand the content better when they provide an explanation (Hand et al., 2004; Rivard et al, 1999).

When the students are involved in this type of discourse, they compare their findings with their peers. They must persuade others that what they are stating is factual and accurate. To complete this successfully, requires the students to have a clear understanding of the conclusion. To think things through clearly, to examine what evidence supports a conclusion derived from experiments, based upon the student's generated hypothesis is a highly desirable skill that will aid in the skills necessary to function as scientifically literate individuals, be able to hold intelligent discussion on a topics that matters, and know how to ably defend their statements

Problem Statement

The research question guiding this study is: Will utilizing the SWH process throughout students' science experiments have a positive effect on their understanding of properties of matter, both physical and chemical, versus the more traditional instructional format.

Purpose

The purpose of this teacher research project is to examine the effect that SWH has on students' understanding of science concepts related to physical and chemical properties, and the changes the materials undergo. My students using SWH will be compared to my students in a traditional teacher-directed classroom setting. Research indicates that when SWH was utilized, students' understanding of the concepts and of the NOS was significantly improved (Hand et al. 2004).

According to Burke, Greenbowe, and Hand (2005):

> "In traditional laboratory format, procedures are uniform for each student, data are similar, and claims match expected outcomes; results and conclusions often lack opportunities for more extensive student learning about the topic or for developing scientific reasoning skills. The SWH (Science Writing Heuristics) is designed to help students think about the relationships among questions, evidence,

and claims. The SWH promotes students' participation in laboratory work by requiring them to frame questions, propose methods to address these questions, and carry out appropriate investigations" (p.3).

In an effort to better understand how to support my students' learning, I elected to implement an SWH process with two of my classes and compare the students' test results with test results from student in my classes that did not utilize SWH.

Rationale

Studies have shown that students often do not develop a measurable understanding of specific concepts while performing laboratory work (Rudd, Greenbowe, & Hand, 2007). Science teachers are challenged because they feel that many laboratories direct students follow to strict adherence to instructions and proper presentation in the write up. This is not a process that supports understanding science within an experimental process. While the types of laboratories that students conduct change to meet current standards, the goal of the laboratory report has remained unchanged: it documents the findings and communicates the results. The SWH is a format that aids the student in processing laboratory experience. This is counter to the traditional laboratory write-up that documents observations and verifies a stated hypothesis. In addition, once written down and turned in, the information is not revised by the student, or shared among students.

This study is important because the current laboratory practices in my school are not effective in preparing students for the world that awaits them (Driggers, 2011; Obama, 2009b; Petsko, 2008). Critical thinking skills are lacking in our laboratories. Most of our laboratories just tell students what to complete when doing the lab.

According to Keys (1999), SWH facilitates students to “generate meaning from data, make connections among procedures, data, evidence, and claims, and engage in metacognition” (p. 1065). Teachers who use this tool are able to help their students think critically and learn science concepts.

Definitions

Basic, Proficient, and Advanced as used in ranking students’ scores on the NAEP, science assessment:

- **Basic** denotes partial mastery of prerequisite knowledge and skills that are fundamental for proficient work at each grade (NCES, 2012)
- **Proficient** represents solid academic performance. Students reaching this level have demonstrated competency over challenging subject matter (NCES, 2012)
- **Advanced** represents superior performance (NCES, 2012)

The **Joint Economic Committee** (JEC) is a bicameral Congressional Committee composed of ten members from each the Senate and the House of Representatives. There are ten Democrats and ten Republicans on the Committee. The JEC was established by the Employment Act of 1946 (Public Law 304) (www.jec.senate.gov/)

Misconceptions refer to beliefs that students hold that contradict accepted scientific theories (Eryilmaz, 2002)

Science Writing Heuristic (SWH) is a writing-to-learn tool that utilizes templates for the teacher and the students that guide the laboratory activities such that SWH promotes thinking and negotiates meaning during the laboratory activities (Hand et al., 2004)

Traditional Lab Report format usually consists of: title, purpose, procedure, data, results, conclusion (Poock et al., 2007)

CHAPTER 2

LITERATURE REVIEW

What is Scientific Literacy?

According to the National Research Council (NRC) in their National Science Education Standards:

> A person is scientifically literate if they can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately (1996, p. 22).

Background

In this day of technology, information is freely and readily available yet the accuracy of the information may or may not be questionable. People are ready to accept whatever they see in print without confirming the reliability or validity of the information. The majority of the population is unfamiliar with the methods of science, and they are unaware when faulty conclusions are drawn from presented materials.

People must be taught critical thinking skills and science methods so that they know how to critically examine information for bias and ask themselves if the evidence supporting the information is reliable and valid. People need to be educated so that they will not succumb to opinions, but be able to think for themselves and form their own opinions that are based on evidence (NSF Indicators, 2014). A scientifically literate nation functionally requires citizens to be able to discern scientifically sound information from that of pseudo-science in order to make well-informed decisions (NSF Indicators 2004 and 2014).

Time reveals that it is the scientists, engineers, inventors, and researchers (among others) who have shaped our world into what it is today. Listed below are just a few brief examples of science and technological advancements that impact our lives, livelihoods and our planet.

- transportation (bicycle, autos, trains, planes, spaceships, space stations)
- communication (telegraph, telephone, cell phone, Internet, satellite)
- lifesaving (stethoscope, medicine, x-rays, MRI, artificial organs)
- lifestyle (eyewear, plumbing, electricity, appliances)
- security (tanks, bombs, night-vision, radar, drones)

"Science and technology drive the economy, albeit with a substantial time delay… and literally create entire industries, secure our nations against national threats and terrorism, and improve our overall health and wellbeing" (Driggers, 2011, para. 2). As Driggers points out, the invention of the airplane, eventually lead to a multi-billion dollar industry that employs many thousands. As of this writing there are almost 450,000 people employed by the airline industry (U.S. Department of Labor, 2015). In addition, the large STEM-oriented corporations that produce products, services, or information, involve many non-STEM employees as well: managers, secretaries, janitors, etc. (Driggers, 2011; Petsko, 2008).

Many of these industries, which were built upon scientific discoveries, are facing a shortage of workers. As of the year 2010, 33% of the current STEM workforce were over the age of 50 and will be eligible for retirement between now and ten years from now (NSF Indicators, 2014). This crisis is due to a decision made by the majority of today's youth to not take STEM courses during college. Furthermore, this decision has and will result in a critical shortage of STEM workers. Currently, our national shortage is filled with foreign-born and educated people (NSF Indicators, 2004). Additionally, due to the reductions in the number of Visas accepted into the United States, the number of non-Americans to fulfil those positions has declined. Recently the numbers of Visas approved have begun to increase, but it is imperative that there is an increase in U.S. STEM workers (Casey, 2012; NSF Indicators, 2004).

Furthermore, prior to 2008, the majority of all patents granted worldwide originated from the U.S. However, this number has dropped to below half of all patents issued worldwide (NSF Indicators 2014, Chapter 6; uspto.gov, 2013). Many people are now asking, "Has America lost its innovative edge?"

The real question we should be asking is how can science teachers prepare students to become the critically thinking, scientifically literate citizens this country needs and in the process encourage more students to pursue STEM careers and be able to fulfil this country's current and future workforce needs? Science teachers must reach out to their students and stress to them the importance of STEM and in the process, teach them to become scientifically literate. Teachers must expose their students to the realities of different science careers so that the students may re-think their misconceptions of what scientists look like and what one does in his or her job. Teachers must help students recognize the individual, community, economic, and nationwide benefits of pursuing a STEM career. The teachers should be sharing the statistically significant benefits of pursuing STEM careers versus non-STEM careers, (Casey, 2012; Langdon, McKittrick, Beede, Khan, and Doms, 2011; NSF Indicators 2014) a few of which are listed below: STEM workers generally earn a significantly higher income than non-STEM workers.

- In 2012, half of the STEM workforce earned more-than-double the median income of the U.S. workforce ($78,270 or more, compared to $34,750).
- STEM workers without a degree earned, on average, $9/hour more than similar non-degreed, non-STEM workers.
- STEM-degreed workers usually earn a higher income than non-STEM degreed workers even when employed in non-STEM jobs.
- During the recent recession unemployment reached almost 10% in 2010, whereas STEM related positions reached a maximum of 5.5% in 2009, at which point unemployment rates for STEM positions then started declining.
- Since 1960, while the inclusive U.S. workforce has maintained a 1.5% overall growth rate, STEM related positions have maintained a 3.3% growth rate annually
- Between 2010 and 2020 there is an expected 17% increase in STEM positions compared to a 10%-14% increase in non-STEM positions.

In 2009, as a response to American students being outperformed by almost half of the participating countries in reading, mathematics, and science on the Programme for

International Student Assessment (PISA), President Obama demanded action. In addition to these statistics, he brought up a concern over the number of STEM jobs that were being outsourced to other countries because of the lack of STEM skilled workers within the U. S. This resulted in President Obama initiating Race-To-The-Top (RTTT) and Educate-to-Innovate initiatives. Obama also formed a committee The President's Council of Advisors on Science and Technology (PLAST), who advises him on all issues related to technology. PLAST has specifically stated "… the Nation must ….prepare all students to be proficient in STEM subjects…. inspire all students to learn STEM and, in the process, motivate many of them to pursue STEM careers" (Report to the President, 2010). In support of STEM development, Obama has allocated federal funds for states however they must compete for the funds. To qualify, some of the criteria are: states must strive to increase both the number of STEM courses offered in schools as well as increase the enrollment in those classes, particularly within the traditionally underrepresented sections of our population (women and minorities), and increase student test scores in STEM.

George Tellis (Chair of American Enterprise, Director of the Center for Global Innovation, and Professor of Marketing, Management and Organization at the USC Marshall School of Business) disagrees with Obama. It is Tellis' (2013) opinion that American students are outperformed on standardized tests, when compared to test scores of students from other countries because U.S. schools "do not emphasize rote learning, which leads to good performance on standardized tests" (para. 6). He feels U.S. teachers are competent as they encourage independent thinking and do not enforce rote learning with their students. Tellis does believe that if someone could develop a test that could measure excellence in entrepreneurship then our students would excel (para.7).

Tellis (2013) feels the real reason that the U.S. has lost some of its competitive edge with patents and innovation is because of the changes to immigration. This country was founded on people who were "persecuted and rejected" (para. 9) and when they arrived here they felt welcomed and brought with them new and different ideas. His thoughts are that U.S. has begun to close the door on immigrants and in the process is losing all the new ideas that arrive with "new people" (para. 9).

Motivation

The best way to encourage students to engage in science is through their teacher. Student learning is impacted by their motivation. Students may lack motivation for any number of reasons: not interested, too easy, distracted, special needs not met, or not relevant (among others). To motivate students, teachers must be interested in the topic themselves. If the teacher is disinterested, the students will sense that and may also feel the topic is not important for them to focus on. Teachers must find ways to make the topics relevant to the students; link the topics to 'real life' in ways that they want to know more. Another way teachers can motivate students to participate in their learning is to allow them to work socially. SWH utilizes social interactions therefore is an excellent tool for increasing motivation. "A classroom environment that fosters social interaction is more likely to foster intrinsic motivation more than individualized, solitary learning environments" (Block and Mangieri, 2009, p. 79).

SWH Literature

The traditional laboratory write-up (see Figure 2) is utilized to conduct laboratory activities that are designed by the teacher in order to reinforce the teaching.

Figure 2

Traditional Laboratory Write-Up Format

Traditional Lab Write-Up

1. Title
2. Purpose – What questions do we want to answer?
3. Procedure – How will we find out the answers?
4. Data – Observations and Measurements
5. Results – Summary of the Data (graph, chart, table)
6. Conclusion – How did our results compare to our purpose?

Traditional laboratory activities do have value in that they reinforce science skills (measuring, using equipment, safety, etc.) and teach the students how to work together for a common goal. Without additional guiding questions, this format is not designed for the student to generate meaning of what occurred nor are the students expected to use their evidence to make a claim. The traditional laboratory write-up may require the students to make sense of their results but more from the perspective of whether their result supported their hypothesis. However, unlike the SWH, the traditional laboratory write-up is compartmentalized: purpose, hypothesis, experimental design, data, and conclusion; the conclusion answering the question of whether their hypothesis was correct or not. This fails to make the laboratory experience personal for the students.

SWH, on the other hand, joins the discrete parts of the laboratory experiences together and makes it more of a personal and therefore meaningful experience. Instead of answering section headings (purpose, hypothesis, design, data, conclusion), the students write to themselves:

- What I want to know?
- What I think will happen?
- What did I do?
- How do my ideas compare with my peers?
- What do others' think?
- What claim can I make and what evidence to I have to make that claim?
- How have my ideas changed from before I did this activity?

This modification to traditional educational laboratory activities and write-ups, with the way the SWH chooses wording, changes the intent of the laboratory activities to move away from a "set of procedures that demonstrate knowledge into something that requires a more active epistemic role for students" (Yore, Bisanz, and Hand, 2003, p. 713).

Keys, Hand, Prain, and Collins (1999) describes SWH as a tool that helps students construct a conceptual understanding of science topics through laboratory activities that are guided by templates; one template guides the teacher and the other guides the students (see Figure 1). Studies have shown that when students utilize SWH effectively, their construction of scientific meanings and conceptual understanding is improved (Hand, Wallace, & Yang, 2004; Keys et al., 1999; Nam, Choi, & Hand, 2010; Poock, Burke, Greenbowe, & Hand, 2007; Rudd, Greenbowe, & Hand, 2007; Wallace, 2004; Yore, Bisanz, & Hand, 2003). The SWH process has several qualities which are supported by educational work and research based data.

SWH uses collaborative learning and thus has been found to support student learning (Block and Mangieri, 2009; McLeod, 2014; Osborne, Simon, Christodoulou, Howell-Richardson, and Richardson, 2013). Osborne et al. (2013) found that the "empirical evidence of social psychologists revealed that students benefited from peer discourse and through it gained knowledge and understanding" (p. 316). Additionally, the National Science Teachers' Association (NSTA) recognizes the importance of social collaboration as they report that they expect science teachers to provide regular opportunities for students to "collaborate effectively with others in carrying out complex tasks, share the work of the task, assume different roles at different times, and contribute and respond to ideas" (NSTA, 2007, p. 2).

Adolescence is a time of confusion; students at this age are uncertain about the changes occurring within their bodies and where they would 'fit in' with other students (Knowles & Brown, 2000). Adolescence is also a time when these students have re-entered the egocentric stage. Unlike egocentrism of a young child, the adolescent understands that people think differently however, they are consumed with the notion that everyone is "watching and analyzing them" (Wookfolk, 2004. p. 39). This fixation may be that they are certain everyone sees the pimple on their face or that everyone thought that their response to a question was stupid. This may cause adolescents fear and anxiety when forced to respond to a question or share their experiences in front of the entire class (Knowles & Brown, 2000). SWH arranges for students to interact frequently and in smaller, more intimate groups. Having knowledge of the social and cognitive behaviors of the adolescent, the teacher can utilize SWH to assist these delicate students to work with their peers to build positive relationships and attitudes about science and about learning.

As a result of the many changes that occur, physically and cognitively, the adolescent is uncertain as to what constitutes "normal" and therefore "rely on peers to lead them in the right direction" (Knowles & Brown, 2000, p. 25). To the adolescent student, peer approval "is an extension of the desire to have their personal choices validated" (p. 25). When students were asked, what was the most important thing to learn in school [middle school], one young man responds that it was "How to make friends and how to act…." (p. 22). The science teacher has the opportunity to utilize laboratory experiences such that the students learn in the social setting. The challenge is to structure the time and teach the students how to utilize their social time with focused engagement on the learning task and not get side-tracked with non-relevant social conversation (Yore, Bisanz & Hand, 2003, p. 697). SWH encourages social interactions among the students while guiding them through laboratory activities and fostering science learning.

Cervetti, DiPardo, and Staley (2014) provided three reasons that peer collaboration supports science learning:

- provides opportunities for sharing knowledge and co-reasoning,
- provides collaborative scaffolding, and
- provides for trial and error (p. 548).

Several studies reinforce the idea that providing the students with opportunities to share knowledge and to reason out ideas with their peers supports science learning and builds meaning. In addition to the above reasons there is a written component to SWH that also augments the process science learning.

Nam, Choi and Hand (2010) wanted to examine the impact on student learning by the introduction of peer discussion into laboratory activities among students who had never, previously, been exposed to these opportunities in a classroom setting. The participants of their study were 345 students in 8th grade general science classes from three different schools (schools A, B, C) in Korea. The three schools were classified as lower socio-economic status (SES), located in the second largest city in Korea, and during the past year had received low scores in the Korea national standardized achievement test. As teaching in Korea is predominantly teacher-directed, the students were unaccustomed to participating in peer-discussions. During the experiment: Teacher A, who had taught for 23 years, taught two SWH classes and one control class. Teachers B and Teacher C each taught two SWH classes and two control classes. Teachers B and C taught a total of 13 years and 3 years respectively. All three teachers participated in professional development to (a) implementing SWH (b) practice using SWH, and (c) design lessons for their unit on electricity for the students in the SWH group and the control group. One of each of the teacher's lessons was video recorded. All students were evaluated based on a summative writing where the students were to explain to a friend about electricity. Video recordings revealed that the students at Schools A and B were provided with better opportunities to negotiate meaning within and among groups in their class. This was not the case with the SWH group at school C. The students in the SWH groups at schools A and B were better able to relate their thinking and understanding of electricity in their summative writing than were their control group counterparts. However, there was no significance in difference between the SWH students and the control students at school C. This study demonstrated the effectiveness of SWH on student learning but additionally, showed the limitations to SWH when not presented effectively.

Hand, Wallace, and Yang (2004) found that 7th graders demonstrated improved understanding by scoring higher on the posttest when SWH was 'effectively' incorporated into their laboratory activities than those students who did not receive the SWH treatment. Hand et al. (2004) set up a control group and a treatment group but divided their treatment group into two sub-groups (SG and STG). The SG sub-group received the SWH treatment then concluded the activity with a final written project report as did the control group who did not go through the SWH process. However, the STG students had an additional writing component added to their study. The STG students were required to write their own textbook version of what they learned to an inexperienced audience (students at another school). The STG students were able to demonstrate a better conceptual understanding than the SG students or the control group.

A total of twelve students from SG and STG groups of Hand et al.'s (2004) study were interviewed and asked to reflect on SWH and on their learning. Those students that were interviewed provided valuable insight into why SWH increased their learning. First they felt that having the opportunity to frame their own questions that they intended to investigate caused them to be more engaged. They felt that this made it personal and they were doing their own research versus following instructions for a laboratory activity (p, 142). Also, the majority of the interviewed students (10 of 12) felt that the peer discussions contributed to their learning. Students shared that "hearing their peers' explanations and having an opportunity to share their ideas in the group" (p. 143) helped with their conceptual understanding. Another benefit shared, during the interviews, was that when the students worked together in groups, they shared the "cognitive burden in the difficult task of creating claims" (p. 143). These students also reported that SWH made them think in ways that they had not had to with laboratory investigations performed the traditional way. One student reported that "Not only did we learn, but we found how to learn" (p. 143).

A limitation to Hand et al.'s study (2004) was that they chose to exclude data from any students that were in special education (SPED) or were English language learners (ELL). The researchers reported that those groups were excluded from data analysis to avoid "confounding effects between the treatment and the students' special needs…" (p. 135). This leaves the reviewer of this study to question whether those excluded students were decided upon prior to the investigation or afterwards when results were evaluated. Teachers wishing to improve upon their teaching and enhance learning must address the needs of all students in their classes. This information may have proven valuable to have shared with other teachers or researchers, even if results conflicted, for further investigation.

SWH increases student learning because its structure sets the laboratory activities up such that the students develop their own scientific questions for their investigations. In addition to demonstrating an increased understanding of conceptual learning, students shared in interviews, and teachers observed in the classroom setting, that students were more engaged and assumed more ownership over the investigation and learning when they believed that they were in charge of what to investigate; thus creating an initial interest in the topic and therefore resulting in buy-in (Ende, 2012; Hand, Wallace, & Yang, 2004). When utilizing SWH and framing their own questions, students entered into the mindset that they themselves decided, through teacher-guided discussions, what scientific question they were seeking to answer. SWH is a tool that initiates student discovery and influences their learning; the curiosity to pursue the investigation (Ende, 2012; Hand, et al., 2004; Polacek & Kelling, 2005).

Ende (2012) also found that his 8^{th} grade students were more engaged with their investigations when they decided their own questions. Ende did not utilize SWH but he found that the students were dis-engaged with his traditional teacher-directed laboratory experiences and began incorporating a few full-inquiry laboratory experiences throughout the semester. Ende started the school year having his students complete partial-inquiry laboratory experiences so that they were familiar with his expectations of experimental design. The process of slowly moving from partial-inquiry into full-inquiry was beneficial to the students. When it was time for the students to frame a question, Ende provided ideas and guided the student with tips for good scientific questions. He gave the students a general topic and some example questions and permitted the students to choose their own investigation. Ende's experiences showed that the students were much more involved with their projects when they chose their own questions. Ende required the questions to pass his "three barriers" test:

- test subjects could not be "hurt, embarrassed, or stressed"
- materials must easily attainable from home or school
- they must choose a topic that interests them (pp.45-46).

Ende's (2012) students worked on their own individual projects but he provided several opportunities for the students to discuss their projects and for the students to provide feedback to each other. Ende also has the students share their written reports with their peers at several times throughout the entire process so that the students could get ongoing feedback as well as encouraging students to not wait until the end of the project to complete their written report. Ende does not state that his inquiry laboratory experiences assist the students with conceptual understanding or improve test scores but he does state that the students' scores are better on those laboratory reports, the reports appear to be a better benchmark of their understand of the content, and more importantly the students are "better able to make connections between content studied and the real world" (p.50). These experiences are providing the students with a better understanding of the nature of science.

The SWH supports argumentation. Several studies have found that when students engage in scientific argumentation, their conceptual learning is increased (Yore, Bisanz, & Hand, 2003). During the SWH activity, students explain the research process clearly to their peers. This provides the students with a valuable opportunity to improve their understanding, all before having to write it down formally (McDermott, 2010). Osborne, et al., (2013) recognized that when students engaged in argumentation, the improvement to conceptual understanding was significantly increased when compared to other forms of learning. The value in this argumentation is that it develops the students' reasoning skills.

Choi, Notebaert, Diaz and Hand (2010) studied argumentation with students in grades 5, 7, and 10. The students utilized the SWH approach with a few laboratory activities. These students were not compared to a control group. This study had several limitations: the content topics differed, the teachers' pedagogy was not studied, and classroom dialogue was not monitored. This study did not examine the gain in conceptual understanding but was instead investigating students' abilities to make connections within their laboratory experiences and write an argument to that effect. The evaluation was based on written reports of their laboratory experiences. The 5^{th} grade students were able to write "moderate to powerful" (p.161) arguments whereas the 7^{th} and 10^{th} graders arguments were weaker than the 5^{th} graders' arguments. The teacher for the 5^{th} grade students spent more time teaching them to write well and required them to devote an entire page to writing their reflections. The researchers feel that more study should be conducted on the writing of reflections and the connecting of data to formulate claims and evidence. While the 7^{th} and the 10^{th} grade students wrote weaker arguments, they did show improvement when examining their 2^{nd} laboratory report to their 1^{st} laboratory experience. The older students also showed that they struggled with writing arguments and the researchers feel that more time should be devoted to teaching the writing components of scientific arguments.

According to Keys et al., (1999), "textbooks and teachers often present science as a straightforward logical method for finding solutions, rather than as a process of trial and error, uncertainty, justification, and social acceptance of conclusions" (p. 1066). This is not the goal for science education. Science education's goal is to teach and prepare students to become scientifically literate. The SWH is a series of activities that guide teachers and students in their thinking and more closely aligns with the trial and error aspect of the true NOS (Hand et al., 2004; Keys et al., 1999).

According to Hand et al. (2004), this tool, SWH, promotes thinking, helps students to negotiate meaning and improves their writing about science laboratory activities. When students discuss their ideas with each other, it provides them the opportunity to make sense of what they did and make sense of their data. By the same token, this further cements the students' conceptual understanding which is then further strengthened when the students write down their information coherently and to an intended audience. Studies reveal that there is benefit to students' writing when their teacher is not the intended audience. If the students' audience is their peers, they must write differently and explain themselves differently than if they had written to the teacher (Hand et al., 2004; McDermott, 2010).

Teacher implementation has an important impact on the students' benefiting by the use of SWH. Nam et al. (2010) found that of the three teachers in their study, one was not effective at implementing the process. The three teachers' lessons were videotaped. Researchers rated the videotaped lessons for specific criteria related to the implementation of SWH and found that one of the three teachers did not really rate any differently between her treatment group and her control group. Likewise, her students showed no significant difference is in the evaluations between the control groups and treatment groups. The other two teachers in that study showed that they were effective in implementing SWH and likewise their treatment groups outperformed their control groups in their evaluations.

Ende (2012) found that when his students performed their laboratories in the traditional format, engagement was lost between the laboratory activities and their write-up. Ende acknowledged that in addition to his students disliking completing traditional laboratory write ups, he disliked grading them also. Ende felt that his feedback comments were repetitious and usually ignored by the students (pp. 44-45). Ende does not mention the SWH process (and I am unaware if he was even acquainted with SWH) however, as he became a more experienced teacher, he converted three or four of his "traditional" laboratories to an "open-inquiry lab format" (p. 45). Many aspects of the SWH were incorporated into his teaching, whether he was aware of this process or not. He allowed his students to choose their own question to investigate, one that interested them and fell within the concept that he had assigned. The students could work on this project at home as well as at school. For example: when the topic assigned was animal behavior, one student chose to "investigate how long it took for a pet golden retriever to associate a song with dinnertime" (p. 45). Ende found that his students were considerably more engaged, made more and better observations, discussed their findings frequently with their peers and also were earning better grades on those laboratories than when compared to their 'normal' laboratories. The students appeared to enjoy themselves and several chose to do follow up investigations on their own. The students' final reports were publicly displayed where other school members could see. This strategy encouraged more effort from the students and well-written coherent thoughts (McDermott, 2010). The concept of students generating their own questions resulted in an increase in interest and buy-in. Allowing the students to design their own investigations permitted more opportunities for trial and error which more closely reflects the true NOS. The students discussed their findings with their peers frequently and received feedback from each other. The audience for their final report was the school body. Writing to a non-expert audience affects the effort and quality that students will put into their writing (Ende 2012; McDermott, 2010). Ende found those open-inquiry laboratories so successful and wished that he could incorporate them into the schedule every few weeks. Unfortunately those open-inquiry laboratories consumed a great deal of time for the students to complete and for him to provide feedback made it unrealistic (Ende, 2012, p. 50).

Akkus, Gunel, and Hand (2007) pointed out that because SWH critically focuses the students on "the development of links between claims and evidence, it also has the potential to build learners' understanding of the nature of science, strengthen their conceptual understanding, and engage them in the authentic argumentation process of science" (p. 1748). This process builds within these students the skills needed such that they will eventually be the scientifically literate citizens that our society and workforce need and that our presidential administration is demanding.

Is SWH Effective with all students?

Akkus et al. (2007) repeated that research is limited with respect to examining the implementation of SWH on students of differing cognitive abilities or of differing demographics. Akkus et al. did however, report that Rivard (2004) (as reviewed by Akkus et al., 2007) studied whether students of different level ability levels were effected differently when their science activities involved "various language-based activities" (p. 1750). It was found that low achieving students benefited when they had the opportunity to "engage in peer talk about explanatory tasks" (p. 1750). Peer interactions provide low achieving students the opportunity to construct meaning. The opportunity to put thoughts into words has benefits in that it helps students identify how well they truly do understand. Through the process of verbalizing newly learned concepts, students are better able to integrate these ideas into their mental framework which enhances their meaning, and is positive in helping the students fill in the missing gaps that exist in their understanding. By having the opportunity to completely state aloud what the student is thinking and cleaning up any confusion, the student is better able to put their thoughts into writing (McDermott, 2010).

Zohar and Aharon-Kravetsky (2005) (as reviewed by Akkus et al., 2007) feel that the achievement level of students is an important determinant of the effects of an instructional approach on students' science learning" (p. 1750). It is their findings that "high-achievers benefited from a cognitive conflict [as SWH provides] teaching method while their progress was hindered by a direct teaching method. In contrast, the situation for low-achieving students was reversed; that is they benefited from direct teaching while their progress was hindered by cognitive conflict teaching method" (p. 1750). This however contradicts my own findings within my own teaching experiences.

Science teachers have an important task at hand; that task being to utilize laboratory experiences towards meaningful conceptual understanding. Teachers must provide motivational opportunities so that all students will develop critical thinking skills and become scientifically literate. SWH is a powerful tool that, when properly presented, provides science teachers a method to implement and foster a "science-centric" way of thinking in our students.

CHAPTER 3

METHODOLOGY

Research Design

The design of this study is a teacher research project. This research project examined how my students' understandings of physical and chemical properties and changed from pre-assessment to the post-assessment. This is a teacher research project because the teacher (myself) applied a treatment intervention to two classes and compared these students to a control class. This type of research assumes that I, as the teacher, reflected continuously upon my approaches and adjusted them accordingly. The reflecting, adjusting, and accommodating are meant to improve the teacher's instruction and meet the diverse needs of her students (Carr and Kemmis, 1986; Riel, 2010).

Why physical and chemical properties?

The understanding of physical versus chemical properties is a standard established by the state of Arizona that all eighth graders must learn; it is therefore a mandated section of the 8th grade curriculum. It has value to the student in that, as a content item, this topic is a precursor to several topics in physics and chemistry.

In addition, this content is found in everyday life. As students learn about physical and chemical properties, they begin to notice these in their everyday world. Through discussion and through their lab experiences, the students will gain an understanding that products that they have in their homes, and the different properties associated with these products. For instance, they can learn that water exists in different forms when energy is added. They will also learn that there is a difference between chemical and physical properties. For instance, they can learn that steel wool will change when water and air are present or that yeast will change when combined with warm water and sugar.

Why Science Writing Heuristics?

When conducting laboratories in the teacher-directed manner, it is a common to give students a question to investigative. The SWH format allows students, guided by the teacher, to determine their own investigative question. This fosters within the students an initial interest or a “hook” in the investigation. By asking their own question, students assume ownership of their learning, which creates a “buy-in” that leads to an increased chance of students carrying out their investigation. This process also creates a learning experience that allows the student to learn about a concept in a way that is important to him or her (Hand et al. 2004).

In the traditional teacher-directed approach, the instructions, materials, questions and conclusions are provided to the students. In this model, the students follow all the procedures, using a prescribed step by step “manual” and document their observations. They experience the “wow” factor of seeing the product of the reaction produced by the experiment, but miss the benefits of reasoning through the “why” of the experiment.

Subjects and Setting

The subjects of this study are my students and attended a junior high school in Arizona. The school is a Title 1 school with a population of just over 900 students and is located in a community in which many of its residences are below the poverty level. At the time, 82% of this school’s students were currently receiving free or reduced-price lunch. This year the school had enacted, for trial purposes, having breakfast delivered to every classroom each morning. The rationale behind this was that many students came to school hungry and this would help them to be able to concentrate on school instead of their hunger. In addition, its purpose was to expose the students to two good meals on Friday, and to help get them through the weekend until they arrive back at school on Monday. The demographics of the school are displayed in Table 1.

The students meet for science class every school day, and the vast majority of eighth grade students take general science. The only students not taking general science class are those in an advanced tract. I and my five eighth grade general science classes were the subjects of this study. I am a Caucasian woman; age 46 and this was my 4th year of teaching. I hold a bachelor's degree in Elementary Education (K – 8th grade), am certified in general science, general math, and in secondary education. Prior to teaching, I worked for 15 years in the industrial sector as a chemist and chemical technician. I am currently enrolled in a Master's Program, and this is my culminating research project.

Periods 3 and 5 were the treatment group; periods 1, 2, and 4 were the control group. All groups were heterogeneous, with mixed-ability levels. Eighteen percent of the subjects had an excessive absentee rate. Excessive absences were defined as qualifying for an audit status in class; which is designated as a total of classes missed of 10 days or greater per semester. It is notable that the majority of those students categorized as having excessive absences had exceeded 20 days absent that semester.

Table 1:

Subjects' Demographics

Subjects	n	Girls (%)	Boys (%)	White (%)	Black (%)	Hispanic (%)	Native American (%)	Other (%)	English is Primary Language (%)	Free/ Reduced Lunch (%)
		n=7	n=9	n=4	n=4	n=6	n=2		n=11	
Treatment Group	16	44	56	25	25	38	13	n/a	69	n/a
		n=16	n=9	n=4	n=3	n=13	n=5		n=16	
Control Group	25	69	31	15	12	58	15	n/a	64	n/a
Participating School	~900	n/a	n/a	24	9	53	13	1	59	82
Participating School's District	~75,000	n/a	n/a	50	5	38	5	2	75	n/a

School and District Data Source: Mesa Public Schools Department of Research and Development: Demographics of All Schools updated October 2014 pp.55 & 65 Retrieved from: http://www.mpsaz.org/research/parents/demographics/files/2-oct_2014_all_schools_combined.pdf

Intervention

Three weeks were allocated for this teacher research study project. The unit taught involved direct instruction, textbook reading in individual and group settings, and participation in six laboratory activities. Both the control and the treatment group were provided with the academic expectations for this unit. Both groups received identical direct instruction and had access to the same textbook and resources. The following applicable Arizona academic standards were addressed:

- S5C1PO4: Classify matter as mixtures, compounds, or elements
- S5C1PO1: Identify the state of matter of various substances
- S5C1PO3: Identify evidence that a chemical reaction is occurring
- S5C1PO1 & S5C1PO2: Identify different types of matter based on its physical or chemical properties

All activities were completed in groups of two or more to encourage peer support, discourse, and feedback. I explained to all my classes that they would be participating in a study that was looking at different ways for students to conduct and write-up their laboratory experiences. They were informed that I was conducting this study in order to learn better ways to improve my teaching and to enhance their learning. All subjects were unaware to which group they belonged; treatment or control.

The treatment group received an SWH template (see Figure 3) to guide them as they progressed through the activities. They recorded their observations and data on their own copy of the template. The first time they used the template, they received a version that provided guiding questions. This helped them with how to use the template and assisted in guiding them through the new process. After the first laboratory was completed, the other templates had only the leading information as viewed in Figure 5; with allowance for slight wording variances. Emphasis was placed on peer communication with the expectation that upon completion of the laboratory experience, they would present their findings to the class. The control group received the traditional procedures for each lab activity, instructing them what materials to use and the specific procedures they were to follow. This group documented their findings using a traditional lab report template (see Figure 7).

Figure 3:

SWH Template for 1st Time Student Use, Page 1of 4: Student Data

Reactions Lab – Day 1

Reactions Labs Name:	Partner(s):
What are signs that tell us a chemical reaction is occurring?	
Safety Rules when working with chemicals.	
There are four stations. How much time do you have at each station? Allow time to write your observations and draw your illustrations of your observations.	
Station #_______ Name of Lab Station ---------------------------------→ Read instructions completely BEFORE beginning! Before you begin, what do you hypothesize will happen?	
Illustrated Observations	Written Observations (Be Detailed!)
Did a reaction occur? Was it chemical? What was the evidence?	

Note: Page 1 of 4 pages – Treatment group used this form their first time using SWH. Page 2 and top half of Page 3 repeated the portion below the gray mark for laboratory data – to allow for a total of four laboratory investigations.

Figure 4:

SWH Template for 1st Time Student Use, Page 3 of 4: Making Claims/Reflections

What claims can I make now that I completed the four labs?	
What evidence am I using to make these claims? How do I know that I can make this claim?	
Share your results of the labs with groups assigned to you. How do my results compare to theirs?	
Read "Chemical Reactions" Packet. How do my ideas/evidence compare to what I read?	

Note: This is the bottom half of page 3. The top half contains the duplicate of bottom of Page 1 for student laboratory data.

Figure 5:

SWH Template for 1st Time Student Use page 4of 4: Student Reflection Questions

Reactions Lab – Day 1

Reflections:

What did I learn? ______________________________

What would I like to be able to repeat so that I could verify my observations, see what I might have missed? What would I do differently? ______________________________

How have my ideas changed from what I thought would happen before I did the labs? ______________

Reflections on Group Work:

Did everyone participate equally? ______________

Comments about working with your partner(s)? ______________________________

Based on your understanding, **explain in detail** whether melting butter on the stove is a chemical reaction or not? ______________________________

Measures

I administered a chemistry knowledge test prior to the unit (pre-assessment) and at the completion of the unit (post-assessment). I modified the schools' current post-assessment to include illustrations and word banks to accompany the assessment. The assessment contained illustrations and descriptions of the illustrations then required the students to identify first whether the example was a physical change or a chemical change, and then the students explained what evidence supported their answer.

The students identified solids, liquids, and gases from illustrations of objects. The students listed signs that a chemical change occurred. The balance of the assessment contained fill-in questions related to the rest of the chemistry unit. Word banks were provided. The assessment contained 41 questions and addressed seven areas. Figures 9-12 provide copies of the assessment.

The data from the control group and the experimental group were analyzed to determine if there were any significant differences in the performance and cognitive learning in those groups of students. The pre-assessment and post-assessment were the same test and were modifications of the accepted assessment for the 8^{th} grade teachers at this school. Based on previous assessment results from prior units and the struggle with these students, mastery of the content was set at 70%.

Procedures

After completing the pre-assessment and to initiate and facilitate a class discussion, all students completed a K-W-L chart (see Figure 6) with respect to atoms and their properties. A K-W-L chart is a three column template that students complete individually or collectively. In the first column they listed everything that they knew about atoms and chemical and physical properties. In the middle column the students listed everything that they would like to learn about atoms and chemical and physical properties. The last column was to be completed at the conclusion of the unit. This column is where the students list everything that they learned and compare to the items listed in column one. Due to time constraints, we did not complete this last column. This activity encourages the students to access their prior knowledge and provides a vehicle on which to scaffold new ideas.

Figure 6:

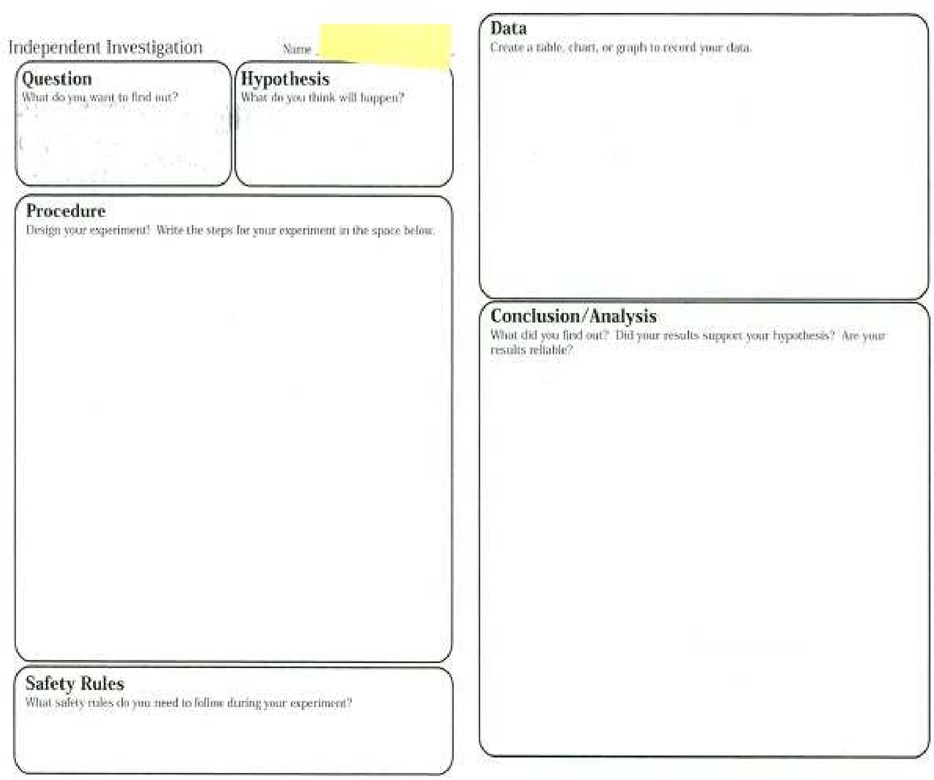
K-W-L Chart

During each activity, students, in both the treatment group and in the control group, were able to work with and discuss their work with their laboratory partners. The students in the treatment group were able to discourse as a class at the conclusion of each activity. The students in the control group were able to discourse with only their laboratory partner at the end of each activity.

At the conclusion of the activities, the control group transferred their knowledge to their formal lab report (see Figure 7). The control group then used their data to determine if their hypothesis was correct or not and then wrote how they knew whether the hypothesis was correct or not. Their laboratory reports were turned in and graded.

Figure 7

Traditional Laboratory Report Format – Student Use Template Pages 1 and 2



Independent Investigation

Name

Question
What do you want to find out?

Hypothesis
What do you think will happen?

Procedure
Design your experiment! Write the steps for your experiment in the space below.

Safety Rules
What safety rules do you need to follow during your experiment?

Data
Create a table, chart, or graph to record your data.

Conclusion/Analysis
What did you find out? Did your results support your hypothesis? Are your results reliable?

Figure 7 has been reduced to fit into this document. These are actually two 8x11 sheets

At the conclusion of the activities, the treatment group was expected to follow the SWH guidelines, step-by-step (see Figure 8). They were to make a claim and provide evidence pertaining to their claim and a rationale to their hypothesis. As per the SWH guidelines, they were to read information about their claim (textbook or article given to them) and compare what they read with what they found with their data. They were then expected to share their findings with the class, and discussed the reasoning for the claim that they declared. This provided the students an opportunity to fine tune their understanding. Their completed templates were then turned in for grading.

Figure 8

SWH Template for Student Use

Name: ________________________________

What questions do I have? **Tests…..What did I do?**	
Observations: What did I find?	
My Claim is: **My Evidence is:**	
What do others say:	
Internal Sources	**External Sources**
Reflection: How have my ideas changed?	

All boxes in this Figure 8 were reduced to fit within this document. Actual SWH template encompasses three 8x11 pages for students' use.

Laboratory Activities:

Activity #1: Sorting elements according to patterns (2 Days)

This introduces the students to the periodic table of the elements. This activity had no differentiation between the treatment and control groups. In groups of four, the students receive a deck of cards that contained elemental information and properties thereof without including the name of the element. Students look for patterns within the information provided to them, and then organize the cards in a pattern that makes the most sense to them. Once a pattern is agreed upon, the groups rotate around the room to observe the patterns that the other groups had created. This activity end with the groups presenting to their classmates: (a) how they fashioned their patterns, (b) what parameters caused them to organize the cards in such a way, and (c) why they chose the pattern they eventually settled upon.

This introduces the students to speaking in presentation form, delivering information to a small group; yet in a relatively safe environment. The groups perform their presentation while remaining at the investigation table where they completed the activity. This prepares the students to speak in front of the class, which will come later in the set of activities. In addition, group discussions give the students a chance to vocalize their thoughts, hear other classmates' thoughts and be allowed to re-examine their own thinking. The students do not have to write anything during this activity, which lessens their anxiety pertaining to being "right" or "wrong". Future activities will require students to formally report their findings utilizing a written format. This activity will be followed by some direct instruction on utilizing their textbooks and on patterns within the periodic table.

Activity #2: Classifying substances as elements, mixtures or compounds; solid, liquid or gas (1 Day)

This activity is preceded with direct instruction on:

- The properties of elements, mixtures and compounds
- The properties of solids, liquids or gases
- A review of what constitutes good observations.

In this activity, there is no differentiation between the treatment and the control group. Twenty jars containing different materials are labeled with the chemical make-up of each material. For example: $C_6H_{12}O_6$ for sugar, C for carbon, or $H_2O + SiO_2$ for water and sand. The jars are placed around the perimeter of the room on the counters, spaced about a foot apart. In groups of two, the students rotate around the room to each station and record their observations. They then discuss and come to a determination whether the material is an element, compound or mixture and then if it is a solid, liquid or gas. They have an opportunity to discuss these ideas and qualifications with their partner as they move along throughout the duration of the activity. They record their data in a written format in their student science journal with an explanation as to why they chose each specific response. In addition to teaching about the aforementioned properties of materials and to stimulate the deductive reasoning processes in the students, this activity has an alternate purpose; to provide an opportunity for the students to practice making good observations.

Activity #3: Identify physical and chemical changes (2 Days)

This activity will be different for the control and the treatment group. In this activity, there is textbook reading about physical and chemical properties of elements prior to the activity. Each group contains four students and an effort is made by the teacher to insure that all ability levels will be represented within each group. Two identical set ups of four different labs are arranged around the room for a total of eight lab stations. There are, at each station, written instructions on how to conduct the lab. The students rotate around and carry out the instructions at each station. They have seven minutes at each station to perform the lab and record their observations using a written format. The control group records their information on a traditional lab report template. The treatment group completes a separate form, created by the teacher which introduces the students to the SWH process. Both groups are instructed that because of time constraints and because instructions are provided, they do not need to record these procedures. Although, SWH process invites the students to develop their own procedures, due to lack of time, I want the treatment group to focus their attention on gathering data and developing a claim.

Based on their observations, the control group determines if the reactions observed were evidence of a physical change or of a chemical change. It is expected that the student compare their data to the information gained from their textbook reading and to information gleaned from class discussions that list common indicators of chemical and physical reactions. For instance, if the students observe bubbling then, based on their reading, they would conclude that that a gas was produced, which is a common indicator that the reaction was a chemical change.

The treatment group also uses their data to conclude whether a change was chemical or physical, but then the students in the treatment group compare their results with a neighboring group and discuss the reasons for their conclusions. The treatment groups will then determine a claim. A claim is a statement that declares that given circumstances such as, observing that reactants caused bubbling, indicates that a gas was produced) is always an indication that a reaction is a chemical changer. For instance, students in the treatment group might claim: Whenever two or more substances are combined and a gas is produced, then the reaction is a chemical change.

The treatment group students are provided an article that reinforces information about evidences that changes are either physical or chemical. The treatment group is encouraged to look back over their textbook for more contextual information. These students document the relevant evidence they observed and compare it with what they read. They reflect on how their ideas about changes being physical or chemical, have changed following the activity with regards to what they were prior to the activity. They are asked to evaluate the validity of their preconceived ideas regarding evidence of chemical versus physical changes in the light of their own personal observations and evaluations of data they generate during this lab activity.

Activity #4: Altering reaction rates (1 Day)

This activity is different for the control and the treatment group. Both the control and treatment students work in groups of two. Both groups are timing the rate of reaction from start to finish when an Alka-Seltzer tablet (an over-the-counter heartburn remedy that reduces acidity of stomach acid) is added to water (the reaction "fizzes" producing carbon dioxide bubbles). Both groups are shown a short video clip of an Alka-Seltzer commercial. The students use stop watches to record the length of time it takes to complete the various reactions.

The control group is told that the purpose of this lab is to determine if altering the temperature [energy] of their reactants has any impact on the rate of the reaction. They record their hypothesis, based on the question (purpose) provided by the teacher, in their traditional laboratory write-up (see Figure 5). This group receives the laboratory procedures to follow for this experiment. Once these students have completed the laboratory experiences, individually they evaluate whether their own hypothesis was correct or not and record what evidence they have to support that conclusion.

In this activity, the treatment groups have at the front of the classroom: Alka-Seltzer tablets, hot plates, buckets of ice, beakers and thermometers to provide visual stimuli. Prior to this activity, the treatment group engages in a class discussion about how they believe they could affect a reaction to cause it to happen quicker or more slowly. The students share ways they made a reaction occur quicker or slower at home or outside of the laboratory environment. This provides a starting point from which to scaffold their new ideas. Once the students have made their suggestions, the teacher divides them accordingly. For instance, the students usually will discuss changing the temperature or crushing the Alka-Seltzer tablets. The teacher will 'suggest' a few groups investigate heating the water, other groups will investigate cooling the water, and a few will investigate when the tablet is crushed. They will not be reminded that they are to compare all results to room temperature and whole tablets. I want the students to apply their knowledge of experimental design. I also know that some groups will forget to run a control test, which will challenge those students when comparing their results. This provides for valuable future class discussions. The treatment group records their information on their SWH template (see Figure 6).

Activity #5: Another look at signs of a chemical change (1 Day)

This activity is different for the control and the treatment group. Students worked in groups of two in both the control group and the treatment group. For this activity, the students are permitted to choose their own partner. In addition, because of time constraints, both the control group and the treatment group receive procedures to follow. The control group recorded their findings on the traditional lab write-up template (see Figure 5). The treatment group record their information utilizing an SWH template (see Figure 6).

The students observe changes that occur when a piece of liver is placed in water versus changes that occur when a piece of liver is placed in hydrogen peroxide. One thermometer is provided at each laboratory station and all student groups have to figure out for themselves how to conduct the experiment with only the limited equipment provided. There are not enough thermometers to provide each group with two. This is an opportunity for the students to practice reasoning skills in addition to developing good laboratory techniques. All students are expected to provide both qualitative and quantitative data.

Lab Activity #6: Formation of a precipitant as a sign of a chemical reaction (1 Day)

Due to time constraints, I demonstrated Activity #6 to all classes. I combined two clear liquids that produced a precipitant, and then I filtered out the precipitant. In a whole class setting, the students shared their ideas as to whether this reaction was chemical or physical and their reasons for their decision. There was no differentiation between the treatment group and the control group.

Data Collection

Prior to the start of the unit, the students completed a pre-assessment to determine their level of understanding of the aforementioned topics. This pre-assessment and post-assessment were the same test and were comprised of 47 questions. Page one (see Figure 9) and page two (see Figure 10) of the assessments were the focus of this study, therefore only their data was analyzed. The data used in this study focused specifically on chemical and physical properties and identifying a change to those properties as either a physical change or a chemical change. Illustrations were provided as an aide. Students that did not achieve mastery of these concepts were provided one opportunity to retake the post-assessment. Only three of the seven students who did not achieve mastery took advantage of that opportunity

During the unit, the activities were collected and analyzed for quality, accuracy and completeness of their descriptions. Examples of good and poor observations were previously discussed with the students so I examined their laboratory write-ups for high quality observations. For accuracy, I observed during the laboratory activities and in the laboratory write-ups if the students had followed instructions completely. I analyzed the write-ups for the students' attention to detail in completing their templates. I expected the students to record qualitative and quantitative data therefore, graded accordingly. During the activities, I observed the interactions of the students; I was looking for cooperation, teamwork, and staying focused on the tasks. I also made adjustments to accommodate changes to school wide environmental and logistical circumstances such as fire drills and assemblies.

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Figure 9

Pre-Assessment and Post-Assessment Page 1 of 4

Name__________________

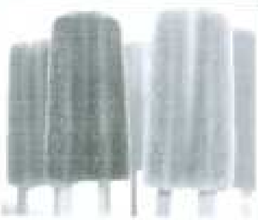
Date__________Period________

CHEMISTRY UNIT TEST

State whether the reaction is a physical change or a chemical change and why. Provide specific details for the "How did you know" (1 pt each)

Baking Soda and Vinegar are placed in the bottle. A balloon is attached to the bottle and gets larger. You are concerned with what caused the balloon to get larger, not the stretching.

1. Type of Reaction: ____________________
2. How did you know? ____________________

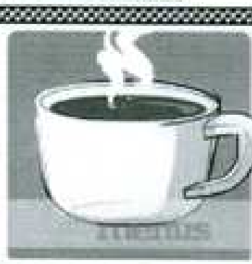


Started out as flavored water now they are popsicles.

3. Type of Reaction: ____________________
4. How did you know? ____________________

Started out as flour, sugar, eggs, butter, and more. Mixed together, baked in the oven for 30min then you have wonderful smelling and delicious tasting cupcakes.

5. Type of Reaction: ____________________
6. How did you know? ____________________



You are enjoying a nice cup of hot cocoa.
What in this picture represents a solid, a liquid, a gas
(1 pt each)

7. Solid: ____________________
8. Liquid: ____________________
9. Gas: ____________________

Figure 10

Pre-Assessment and Post-Assessment Page 2 of 4

Identify which state of matter each molecule formation represents (3 pts)

States of Matter

10.__________ 11.__________ 12.__________

13. Put the words that are in the Word List Box into a category of either a Physical Property or a Chemical Property. (1 pt for each word = 12 pts)

Word List

Solid State	Reacts with water	Size	Volume
Mass	Density	Odor	Reacts with oxygen
Flammability	Color	Liquid State	Gas State

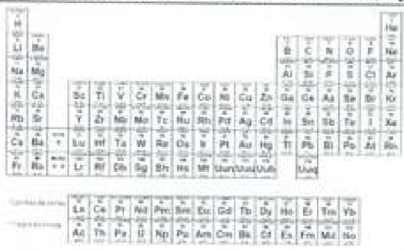
Physical Properties	**Chemical Properties**

14. List evidence that a chemical change has occurred. List at least three. (3 pts)

Figure 11

Pre-Assessment and Post-Assessment Page 3 of 4

Write in the term that best fits the description.



Terms for questions 15-22. (1 pt each)

Oxidation	Family
Matter	Reactivity
Period	Periodic Table
Element	Solubility

15. The above chart that organizes the elements by common properties is called a(n)

________________________________.

16. Na (sodium), a pure matter, is an example of a(n) ____________________________.

17. The elements that run in vertical columns are part of a(n) ______________________.

18. The elements that run horizontal rows are part of a(n) ________________________.

19. Anything that has mass and takes up space (volume) is ______________________.

20. The tendency for a substance to undergo a chemical reaction by itself or with another substance is ____________________.

21. The chemical combination of a substance with oxygen is ______________________.

22. Term for determining if a substance is capable of being dissolved. __________________.

Terms to use for questions 23-24. 1 pt each

Precipitate	Density

23. This term defines the mass per unit volume of a substance.

____

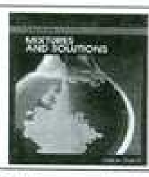
24. This term describes when two soluble salts (usually liquids) react to form an insoluble product. (To fall out – as in rain)

____

Figure 12

Pre-Assessment and Post-Assessment Page 4 of 4

Write in the term that best fits the description.



Terms for questions 25-29 (1 pt each)

Mixture	Homogeneous Mixture	Solution
Compound	Heterogeneous Mixture	

25. These combinations of matter are not chemically combined and may be separated by physical means. ____________________

26. These combinations of matter are chemically combined and cannot be separated by physical means. ____________________

27. Two or more substances not chemically combined but have a uniform composition and properties. You cannot visually distinguish the two substances from one another. Water and salt mixed together would be an example. ____________________

28. One of the two or more substances when mixed together- do not chemically combine nor do they have a uniform appearance. Mixed nuts would be an example. ____________________

29. A homogeneous mixture of two or more substances, usually liquid. ____________________

Write in the term that best fits the description for questions 30-37. 1 pt each.

Exothermic	Physical Reactions	Chemical Reactions	Endothermic
Acidic	Law of Conservation of Mass (Matter)		Basic
pH scale			

30. A chemical reaction that results in energy being absorbed. (gets cold) ____________________

31. A chemical reaction that results in energy being given off. (gets hot) ____________________

32. A change in matter that does not result in a new or different substance. ____________________

33. A change that takes place when two or more substances interact to form a new substance. ____________________

34. Scale used to measure the acidity or alkalinity of a substance. ____________________

35. pH less than 7. ____________________

36. pH greater than 7. ____________________

37. Law that states that mass (matter) is neither created nor destroyed in an ordinary chemical reaction, it only changes form. ____________________

Page 4

Data Analysis

Students completed a content pre-assessment at the start of the unit, and then completed a content post-assessment at the end of the unit. The scoring was pre-determined by the cadre of 8th grade science teachers prior to the unit. Each question was scored at one point per response. The gradebook then factors in the students tests and quizzes as 25% of the students' total class grade. The students were provided word banks for this post-assessment, spelling did not count. The reaction questions were each split into two questions. One point was earned for stating whether the illustrated and described reaction was a physical or chemical change, another point was earned for providing the evidence to support that answer. Another question required the students to list four signs of evidence that a chemical change is occurring. Each sign of evidence was worth one point therefore, this question was worth a total of four points.

The pre- and post-assessments were analyzed using a two-tailed paired t-test. The post-assessments of the treatment group and of the control group were analyzed using a Two-Sample Assuming Unequal Variances t-test to account for the different number of students in each group. After analysis of my situation, it was recommended to use a two-tailed t-test. The recommendation came from a research assistant with the Arizona State University's Education Department.

Illustrations were provided on the pre-assessment and on the post-assessment to accompany the questions. This visual aide was especially helpful for the low-level readers. Approximately 10% of my students read at the 1st through 3rd grade level and of these, only three are classified as special education students. The students that are in the special education classification (SPED) were not analyzed as a subgroup for this study. Of the test subjects, seven percent (three students) qualified for a SPED designation.

The post-assessment required the student to determine, based on the image and scenario description, whether a substance underwent a physical or chemical change. It also required them to provide a brief description and explain why they chose their specified answer. The majority of this post-assessment would be considered lower-level thinking or recalling of information; however some of the questions that are specific to this study required decision making and explanations which raise the complexity of the thinking level required of the students.

Limitations

There were a several limitations to this study. The sample population was small. I had a total of 118 students but due to the requirement that the students returned a signed waiver, I was only able to use data collected on 41 of the students. Assuring accurate representation of the total population in this scenario is not realistic.

In addition, there were several factors. They were:

- While each of my five classes represented mixed ability levels, the school had distributed the students into three cohorts. One cohort consisted of the higher-ability students that were in the advanced classes. These students did not take eighth grade science but were in another program. The rest of the students were split among two cohorts. This resulted in the study being comprised of students that were academically in the lower two-thirds of the population.
- The absenteeism rate was unusually high. One-fourth of my test subjects were absent 13 or more days, the majority of those exceeded 20 days. There were a few test subjects that had between 50-70 days absent that semester. This resulted in re-teaching as students often had a partner one day who was gone the next.

Other areas that are limitations include:

- Small sample size that was further reduced because after the post-assessments were graded, they were returned to the students to review. Five of the qualifying students failed to return their test materials. This resulted in their data being removed.

- My inexperience with the SWH. I had not used this before and did not have a good working knowledge of the instrument.
- Lack of student motivation:
    - Students were reluctant to record their findings (see Figure 13). They wanted to participate in the lab activities but resisted putting anything on paper. Several wrote just a few words and when asked, could not articulate what they had meant.
    - Students were resistant to the SWH approach. There were uncountable instances where the students whined, “Just tell me what to do”. They were not used to reasoning, nor had they had a chance to scaffold into it. It was of thrust upon them and it was different and they fought the process.

Even with these limitations, I feel that this study is worthy. It provides a glimpse into the use of a novel tool to help students learn about science and engage in science. As a teacher research project, it also provides insight into my own teaching.

CHAPTER 4

RESULTS

Overview

All five of my eighth grade general science classes were divided into two groups, two of the classes (the treatment group) utilized the SWH format for conducting lab activities. My other three classes (the control group) conducted their lab activities in the traditional teacher-directed approach. There were 118 students in all but due to circumstances (discussed in limitations) the data was analyzed from only 41 students. The students conducted five lab activities that fit into a larger chemistry module, and observed a sixth activity that was demonstrated by me. Both groups received the same direct instruction and textbook reading assignments.

The unit began with the average pre-assessment scores for both the control and the treatment groups at 52% and 53% respectively. The results indicated that the average gain between the pre-assessment and the post-assessment for the control group and the treatment group was 28% and 19% respectively. The data shows that the students' level of understanding of the properties of matter and the evidence that a property had changed chemically or physically was vastly improved from the start of the unit through completion of the unit. A student is said to have reached mastery if the score was $\geq$ 70% on their post-assessment. At the completion of this unit, 80% of the control group and 69% of the treatment group attained mastery. This is significant and demonstrates that learning relevant to these concepts occurred during the unit for both groups. There was statistical significance between the pre-assessment and the post-assessment for both groups (Control p= 0.000 and Treatment p= 0.000) (See Table 2).

However, according to the statistical analysis utilizing the paired t-test data, the results between the control group and the treatment group were shown as not significant (p= 0.203)(See Table 2).

Table 2

Subjects' Pre- and Post-Assessment Data

		Pre-Assessment		Post-Assessment		Pre-/Post-Assessment	
Subjects	n	Mean (%)	SD	Mean (%)	SD (%)	t-test value* P(T<=t) two-tail	Post-Assessment (%) – Pre-Assessment (%)
Treatment Group	16	53	20.3	72	20.3	0.000	19
Control Group	25	52	22.1	80	20.2	0.000	28
Control vs Treatment	n/a					0.203	

*Significant at the $p<0.05$ level

Table 3

CONTROL GROUP DATA (Paired Samples Statistics)

Paired Samples Statistics

	Subjects	n	Mean (%)	Std. Deviation	Std. Error Mean
Pair 1	Unit Pre-Assessment (%)	25	51.63	22.143	4.429
	Unit Post-Assessment (%)	25	80.71	20.198	4.122

Paired Samples Correlations

		N	Correlation	Sig.*
Pair 1	Unit Pretest (%) & Unit Posttest (%)	25	.412	.000

*Significant at the $p<0.05$ level

Table 4

TREATMENT GROUP DATA (Paired Samples Statistics)

Paired Samples Statistics

	Subjects	n	Mean (%)	Std. Deviation	Std. Error Mean
Pair 1	Unit Pre-Assessment (%)	16	53.12	20.297	5.074
	Unit Post-Assessment (%)	16	72.00	20.301	5.075

Paired Samples Correlations

		N	Correlation	Sig.*
Pair 1	Unit Pretest (%) & Unit Posttest (%)	16	.542	.000

*Significant at the $p<0.05$ level

Table 5:

Students who showed an improvement of ≥20% between Pre-test to Post-test by Demographic Subgroups.

Subjects	n	All Subjects (%)	Girls (%)	Boys (%)	White (%)	Black (%)	Hispanic (%)	Native American (%)
Treatment Group	16	62	71	56	100	25	67	50
Control Group	25	56	62	44	100	33	54	40

Table 6:

Students who achieved ≥70% on the post-assessment by Demographic Subgroups.

Subjects	n	All Subjects (%)	Girls (%)	Boys (%)	White (%)	Black (%)	Hispanic (%)	Native American (%)
Treatment Group	16	69	100	44	50	100	67	50
Control Group	25	80	75	89	75	100	85	60

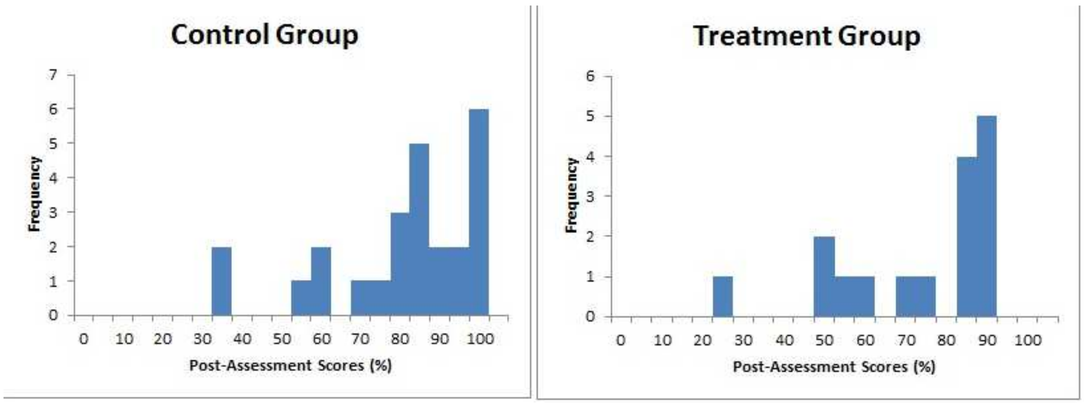
Students who achieved mastery were those that scored at least 70% on the post-assessment. Data were analyzed looking for those who showed a substantial improvement (≥ 20 % improvement) between their pre-assessment and their post-assessment scores. It is important to note, however, that this analysis fails to take into account that the majority of the remaining students (~60%) still achieved mastery but did not require a 20% increase to achieve it. Table 5 illustrates the subgroups of the students (gender and race) who showed an improvement of ≥20 %. Table 6 illustrates the same breakdown by subgroups of all subjects that reached mastery ($\geq$ 70%) on their post-assessment.

The girls in the treatment group outperformed the boys in the treatment group. However, the boys in the control group outperformed the girls in the control group. Forty-four percent of the boys in the treatment group achieved mastery. Of the remaining five boys that did not achieve mastery, two had excessive absences and all four were failing at least three of their content classes. Three of those five boys, who did not achieve mastery, however, did achieve mastery on the portion of the post-assessment that pertained to the questions related to the laboratory investigations.

Eighty percent of the control group and 69% of the treatment group achieved mastery on their post-assessment. To interpret this data, the students are compared to others within their same subgroup. For example, 71% of the girls in the treatment group showed 20% or better improvement when compared to all of the girls within that same group. However, this data does show that as the vast majority of the female students needed less than 20% to attain mastery, 100% of the girls in the treatment group reached mastery on their post-assessment. While the statistical analysis of the significance ($p=0.20$) between the treatment and control groups of this study shows that the type of process to carry out the laboratories did not appear to affect the level of understanding, the actual differential between the groups of 80% (control) and 72% (treatment) bears a different result. Figure 13 represents histograms for the post-assessment scores for both the control group and the treatment group.

Figure 13

Frequency of Post-Assessment Scores for the Control Group (left) and the Treatment Group (right)



The first sixteen questions of the post-assessment were items on which the students conducted their laboratory activities. The balance of the post-assessment, 25 questions, was information that was provided to the students via traditional teacher-directed lectures and note-taking as well as textbook reading assignments. Table 7 reflects the differences in the averages of the entire post-assessment and those first 16 questions that were supported by laboratory investigations.

Results indicate SWH may have had a positive impact on the learning of the treatment group. The number of students that mastered the content involved with the laboratory investigations increased from 69% to 88% for the treatment group. Data shows that there was no change within the control group; 80% reached mastery on the entire unit and 80% reached mastery on the content topics specific to the laboratory investigations.

Table 7

Comparing Entire Post-Assessment to Partial Post-Assessment

Subjects	Full Post-Assessment Mean (%)	Partial Post-Assessment Mean (%)	Difference in Mean (%)	Students Achieved Mastery: Full Post-Assessment (%)	Students Achieved Mastery: Partial Post-Assessment (%)
Treatment Group	72	85	13	69	88
Control Group	80	88	8	80	80

This unit conducted during the study did benefit to the students' learning of the concepts. A typical bell curve of scores of the post-assessment for this unit was not centered on the traditional 70 – 80%. However, roughly 50% of the participants achieved a 100% on the post-assessment for the control group and 56% of the treatment group scored between 80% and 90%, the curve was radically skewed to the right with a mean score of 80% for the control group and 72% for the treatment group. The likely reasons for this can be found in the Discussion. When examining the portion of the post-assessment that was specific to the topics covered in the laboratory experiences and were relevant to this study, the average scores were 88% for control group and 85% for the treatment group.

CHAPTER 5

With the current need for scientifically literate students, as noted in Chapter 1, there is a need to change how we teach science. This need is pressing and immediate, as students are joining a technologically vibrant culture. This study addresses this need by using a SWH with students. This heuristic supports students in their learning of concepts and understanding of the NOS.

The purpose of this teacher research study was to determine if students utilizing the SWH process during their laboratory activities would increase their understanding of the properties of matter and physical or chemical changes involved in matter. From this study, there are four important areas to discussion.

First, the data from the post-assessment revealed that a clearly planned curriculum impacted the learning of the studies. By carefully planning out the curriculum in both classes for this experiment, I had to allocate additional time to understand each instructional sequence. In practicing how I was going to teach the lessons, I unknowingly improved the content structure associated with the control and experimental group. Even though there were different instructional approaches in each class, by practicing the presentation of the lessons and strategically developing the lessons, all of my students improved their scores.

Being prepared to teach is the most important thing a teacher can do. Furthermore, when a teacher is clear on the content outcome, there is often a benefit to students. The extra time that I afforded to the instruction of these lessons was unusual, but it resulted in student learning. Most teachers do not have this sort of time. However, it is clear that understanding the goals of the lessons and practicing the lessons impacted the learning of my students.

Second, the change in student scores could also be attributed to the collaborative nature of all instruction. The SWH requires collaborative learning. In the design of the study, I used the collaborative learning emphasized in the SWH process in treatment and control group. That is, the students in the treatment group and the control group were able to interact with their laboratory partners throughout the activities. The gains made by both groups corresponds to the value of collaborative learning as suggested by Block and Mangieri (2009). They specifically found that when students engaged in collaborative learning, there is an increased likelihood of learning.

In term of the SWH and the collaboration found in the control group, these results are in agreement with prior work. Hand, Wallace, and Yang (2004) reported that peer discussions helped students with their learning. They found more peer interactions and student, group, and class discussions with students using the SWH than in their control group. This data supports the use of collaborative learning in the SWH and in regular instruction.

However, when I started to use collaborative learning, I jumped straight into setting up student discussions without time for establishing norms. There was scaffolding but it was minimal. As these Cervetti, DiPardo, and Staley (2014) indicate, when peer discussions are taking place, the students benefit by learning how to interact with one another. The difference in scores on the partial post-assessment may have been a result of the scaffolding provided to students, which impacted their discourse with one another.

Third, the instructional activities were beneficial to the learning of girls. In my study, there were differences between the performance of the girls and the boys in both the treatment and control groups. In the SWH approach, the girls outperformed the boys significantly. While it would be good that all students do better in class, it is an important finding that the girls are doing better in both classes and significantly different in the SWH class. There are several factors that may have impacted the improved learning of the girls.

One factor may be the importance of talk to girls learning. Girls (generally) do well in classes in which there are opportunities to discuss problems. The SWH class provided a general framework for this to happen. In addition, students in the treatment group were expected to talk amongst their peers. The structure of the class may have benefited the girls, and the added emphasis of discussion in the SWH class may have supported more girls to discuss the phenomena under study.

Additionally, I may have been a role model of a female scientist. I often shared stories and pictures of myself related to the 15 years of chemical laboratory experience I held prior to teaching. It is possible that I positively influenced some of the young ladies, and this small burst of confidence in their view of females in the world of science affected their cognition of the concepts in this unit and therefore their performance on the assessment.

Fourth, I found that a change in instructional activity may not benefit all students. When looking at the data of my study, it is evident that the non-White students did not do as well on the SWH. However, the non-White students improved significantly in the control setting. While this was not expected, there may be an explanation for this result.

It may be that the lesson structure of the control classroom was familiar, and this may have been an advantage to non-White students. With the change in lesson format to the SWH, the students may have struggled to understand what to accomplish.

It may have also been that I unknowing interacted more with the students who were struggling during the control lesson, which may have been the non-White students. As the format of the lesson was familiar to me. I knew how to interact effectively with the students. It may have been that I was efficient in my interactions, which improved the scores of the non-White students in the control group.

In this teacher research project, I had hoped to have a difference between the SWH and the non-SWH groups. This did not happen. Instead, the control and experimental groups had similar results, which were positive gains. The reasons surrounding my results are discussed in the paragraphs above.

LESSONS LEARNED

In performing this study, I learned a great deal. First, I learned that it is important to know how to use methodology. My inability to ascertain whether SWH impacted the learning is hindered by my lack of experience with working with SWH. Additionally, because I do not have clear distinctions between the treatment group and the control group, there are too many variables affecting the outcome. It is important to control an investigation when the output is to compare results.

In addition, I learned that my students are learning during their laboratory activities and I need to turn some of the control of the learning over to the students. The part of me that struggles with giving up control over the classroom needs to recognize that the benefit to doing so will outweigh the initial chaos. I cannot just impart my knowledge and hope the students will comprehend the content because that does not meet the learning styles of many students, nor does it teach them to appreciate the subtleties of the science.

In addition, I learned that it was difficult for me to implement a control and experimental group. I cannot let any of my students falter in my research to better my teaching. Next time, I will implement a teaching strategy to all of my classes and forgo a control group so that I do not have to deny any students the potential benefit.

Suggestions for future study

This study would benefit from the SWH being utilized by more than one teacher, ideally with all of the teachers within a schools science department. This would provide the teachers a chance to provide feedback to each other. Additionally, a cadre of teachers at a school presenting a uniform curriculum and style of teaching curriculum would present to the students a faculty that is backing one-another up and presenting a united front. This uniformity of style would better serve students and reduce the number of students that “fall through the cracks”. I accept responsibility that this study was not performed at an ideal time, yet I believe in its positive, data driven, and beneficial application to the students.

To achieve this, these are some improvements that I will execute next time I implement this teaching tool:

- The students need to see an example of not only what a completed, well-written SWH template looks like, but a poorly written one as well. They need to go over why it is good and what each piece of the template was asking and how the student should respond, on the model template. When discussing types of writing in an English class the students go over poor and exemplary models. Science class pursuing scientific writing should model these "best practices". This will benefit the teachers as well and should be part of a professional development seminar.

- Turn it into a game (remember they are 13 – 14 year old adolescents and love games). Using other samples of well-written SWH forms, separate them, remove the headers from each section, and ask the students to put them into their correct locations and explain to their partners or as a class why they selected the information to go into the specific location they chose. This will build up their confidence level and provide more active engagement and buy-in by the students.
- Still utilizing pieces of a completed form, leave an important piece out and ask the students what is missing. For example, let them read what is present and leave the investigative question out. Once they determine what is missing, ask for suggestions of what the question might have been. The students can provide feedback to each other as to the validity of their answers.
- Let the students list the benefits of utilizing the SWH format. The students in this study were resistant to reading outside sources to back up their evidence. If they determine the benefit that an outside article brings to the sample SWH models, they will be more inclined to do their own research once they are utilizing this process completely on their own.

- Once the students begin to utilize the SWH for themselves, take time to pause at each piece of the template and allow them first to process and discuss what they believe is good and valid information to document. This will take longer to get through a laboratory experience but the benefits far outweigh the loss of time.

I feel that there is a need for more studies that examine the impact of the SWH process with populations of middle school and high school students that live in similar conditions to those described in this study. These additional studies need to include all students in the classroom setting; that they should not exclude students that are SPED or ELL. Teachers must implement strategies that will meet the needs of all of their students in the classroom, not just the willing and able, additional research is warranted.

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